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COST BENEFIT ANALYSIS OF AIRCRAFT TRANSITION FOR NAVY FLIGHT DEMONSTRATION SQUADRON

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June 2019

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In this work, we conduct a financial cost benefit analysis concerning the Navy Flight Demonstration Squadron's (Blue Angels) transition from the current aircraft, F/A-18 Legacy Hornet, to two alternatives, the F/A-18 Super Hornet or F-35C Lightning II. By systematically comparing expected procurement, testing, and operating costs with potential benefits, the methodology we developed in this thesis provides Department of the Navy leadership with valuable data in support of an informed decision on the future of the Blue Angels flight demonstration. Based on the assumptions, methodology, and the findings from our financial cost benefit analysis, our recommendation to the Department of the Navy is to transition the Blue Angels to the F/A-18 Super Hornet for use in the foreseeable future.

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COST BENEFIT ANALYSIS OF AIRCRAFT TRANSITION FOR NAVY FLIGHT DEMONSTRATION SQUADRON

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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

APN	aircraft procurement, navy
AVDLR	aviation depot level repair
CBA	cost benefit analysis
CNATRA	Chief of Naval Air Training
COA	course of action
DoD	Department of Defense
DoN	Department of the Navy
DSCA	Defense Security Cooperation Agency
FMS	foreign military sales
FY	fiscal year
GAO	Government Accountability Office
JIC	joint inflation calculator
JSF	Joint Strike Fighter
KI	Key Influencer
NAVAIR	Naval Air Systems Command
NFDS	Navy Flight Demonstration Squadron
NPV	net present value
OMB	Office of Management and Budget
R&D	research and development

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I. INTRODUCTION

A. GENERAL

The F/A-18 models A-D, commonly referred to as the Legacy Hornet, have been the work horse of the United States Navy tactical jet fleet for more than 30 years. Despite its utility, the airframe is rapidly aging and its technology is struggling to maintain pace with emerging threats. In 2000, the manufacturing facility at Boeing Corporation ceased production on A-D models (Donald, 2019), and as a result, the supply of replacement parts is rapidly decreasing with no future production. While the Navy has begun transitioning its fleet to the more advanced F/A-18E/F Super Hornet and F-35C Lightning II, the Navy Flight Demonstration Squadron (NFDS), the Blue Angels, currently operates the Legacy Hornet. The dwindling supply chain coupled with airframes exceeding their service life poses a significant problem for the Blue Angels as they will potentially be unable to maintain their current aircraft into the future. This report examines the feasible options for the Blue Angels going forward.

B. RESEARCH QUESTION

The primary research question addressed in this study is as follows:

What is the most cost-effective aircraft to replace the Blue Angels' Legacy Hornet given two courses of action (COA)—COA 1: F/A-18E/F Super Hornet or COA 2: F-35C Lightning II?

C. OBJECTIVE OF THE RESEARCH

The purpose of this research project is to carefully analyze the Navy's options in transitioning the Blue Angels from their current aircraft. Our aim is not to debate the value of the NFDS as a continuing program for the Navy given that much research and thought has been previously devoted to this topic. Rather, this project evaluates the most cost-effective of the alternatives to the F/A-18 Legacy Hornet.

This project conducts a financial cost benefit analysis (CBA) on the options for upgrading the Legacy Hornet to either the Super Hornet or the Lightning II. Various costs associated with the procurement, testing, and operation of each aircraft are compared to the benefits (cost savings) generated from using each alternate aircraft to determine the net present value (NPV) or net savings associated with each alternative option. The CBA builds an easily adjustable decision support model that examines the relative strengths and weaknesses of each COA against the status quo, the F/A-18 Legacy Hornet. Based on the methodology and data used in this study, we provide a recommendation to Department of the Navy (DoN) leadership regarding the future aircraft of the Blue Angels.

II. BACKGROUND AND LITERATURE REVIEW

Before attempting to justify a new aircraft for the future of the Blue Angels, it is important to understand NFDS's history and evolution of aircraft over the last 73 years. From the beginning in a single-engine, propeller-driven aircraft to a twin-engine, state of the art jet, the Blue Angels' demonstration has increased in complexity with the transition to each new aircraft. Each aircraft presented for analysis in this project (Super Hornet and Lightning II) have their unique history worthy of discussion.

Additionally, this chapter reviews several programs and a prior study to aid the understanding of the data, assumptions, and methodology that will be used in the cost benefit analysis portion of the study.

A. NAVY FLIGHT DEMONSTRATION SQUADRON

1. Mission

"The mission of the United States Navy Flight Demonstration Squadron is to showcase the pride and professionalism of the United States Navy and Marine Corps by inspiring a culture of excellence and service to country through flight demonstrations and community outreach" (United States Navy [USN], n.d.a).

2. History

Following the successful completion of World War II, then Chief of Naval Operations Admiral Chester Nimitz, saw the need to maintain the American public's interest in naval aviation. His vision was to create an aerial demonstration team to showcase the capabilities of naval aviation. The result was the formation of the Navy Flight Exhibition Team in March 1946 at Naval Air Station Jacksonville, Florida. The team began their demonstration in the Grumman F6F-5 Hellcat (USN, n.d.b), pictured in Figure 1.

Figure 1. F6F-5 Hellcat. Source: Roadkill2525 (2011).

After initial success with their aerial demonstration, the team transitioned to the more powerful F8F-1 Bearcat on August 25, 1946, and continued flying this aircraft for three years (USN, n.d.b). An F8F-1 Bearcat can be seen in Figure 2.

Figure 2. F8F-1 Bearcat. Source: Aular (2013).

In 1949, the Blue Angels were ushered into the jet age with the transition to the Grumman F9F-2 Panther, a standard Navy jet fighter at the time. Due to the emerging conflict on the Korean Peninsula, the Blue Angels were temporarily disbanded and joined Fighter Squadron 191. In October 1951, the Blue Angels reorganized at Naval Air Station Corpus Christi, Texas in the newer and faster F9F-5 Panther (USN, n.d.b). While the performance of the F9F-5 was upgraded, the overall appearance remained the same as the F9F-2. As a result, only the F9F-5 is presented in Figure 3.

Figure 3. F9F-5 Panther. Source: q-zon (n.d.).

From 1955–1957, the Blue Angels performed in the F9F-8 Cougar (Figure 4). The team "continued to fly the Cougar until mid-season in 1957, when they began to transition to the Grumman F11F-1 Tiger. The new aircraft allowed the team to practice flying high, tight, and close. The aircraft also allowed new maneuvers to be added to the demonstration, including the Dirty Loop, a maneuver performed with the landing gears down" (USN, n.d.b). An F11F-1 Tiger can be seen in Figure 5.

Figure 4. F9F-8 Cougar. Source: Arancibia (2015).

Figure 5. F11F-1 Tiger. Source: Jauchler (2018).

By the end of 1969, the Blue Angels again transitioned aircraft to the powerful McDonnell Douglas F-4J Phantom II, which had seen significant use over the skies of Vietnam. This aircraft, depicted in Figure 6, is the only full-time, two-seat aircraft used in the flight demonstration, and it was also the only aircraft to be used by both, the Blue Angels and Air Force Thunderbirds (USN, n.d.b).

Figure 6. F-4J Phantom II. Source: Wikimedia Commons (2012).

Following a devastating tragedy in 1973 in which the Flight Leader and Left Wing pilots were killed along with a crew chief, the Blue Angels were temporarily grounded. Upon reorganization in 1974, the Blues Angels not only debuted a new aircraft with the McDonnell Douglas A-4F Skyhawk II, but they also became an official squadron, vice an exhibition team, and were commissioned as the Navy Flight Demonstration Squadron, with a Commanding Officer that also served as the Flight Leader. This smaller, more agile aircraft is seen in Figure 7.

Figure 7. A-4F Skyhawk II. Source: Kula (2013).

To mark the 40th anniversary of the Blue Angels, in 1986 the NFDS revealed its current aircraft, the McDonnell Douglas (now Boeing) F/A-18 (Legacy) Hornet. This multi-role strike fighter aircraft provided the maneuverability, controllability, speed, and power to conduct the close-quarter aerial maneuvers that have come to symbolize Blue Angel demonstrations. With the Hornet, "the team was again able to perform the Dirty Loop maneuver in formation with the landing gear down—a maneuver still not performed by any other flight demonstration team in the world. The Hornet also allows the team to perform maneuvers such as the Section High Alpha Pass, a slow, high angle of attack maneuver performed by both Solo pilots" (USN, n.d.b). Figure 8 displays the current Blue Angels F/A-18 Hornet.

Figure 8. F/A-18 Hornet. Source: Niesen (n.d.).

The aircraft ultimately chosen to be the workhorse for the future of the NFDS will need to be maneuverable enough to showcase the tight-knit, precision flying of the diamond formation, while powerful enough to provide the maximum performance characteristics demonstrated by the Solo pilots. The long, storied history of the Blue Angels will rely on the F/A-18 Super Hornet or F-35C Lightning II to continue successfully for years to come.

B. F/A-18 SUPER HORNET

1. Mission

> The combat-proven Super Hornet delivers cutting-edge, next-generation multi-role strike fighter capability, outdistancing current and emerging threats well into the future. The Super Hornet has the capability, flexibility and performance necessary to modernize the air or naval aviation forces of any country. Two versions of the Super Hornet – the single-seat E model and the two-seat F model – are able to perform virtually every mission in the tactical spectrum, including air superiority, day/night strike with precision-guided weapons, fighter escort, close air support, suppression of enemy air defenses, maritime strike, reconnaissance, forward air control and tanker missions. (Boeing, n.d.a)

2. History

Following the success of the F/A-18 Hornet in the 1980s and 1990s, the Navy leadership began to express the desire for a similar aircraft with a larger payload, greater fuel capacity, and potential for upgraded technology. In an effort to avoid an entirely new acquisition program, the Navy elected to initiate the Super Hornet program as a derivative of the Legacy Hornet. This upgraded aircraft would retain similar characteristics and components while providing the desired improvements (Boeing, n.d.b). According to Boeing, the result was the F/A-18E/F Super Hornet, an aircraft 25 percent larger than the original with more powerful engines, greater payload capacity, and a longer combat radius. The two variants of this aircraft are the single-seat E model and the two-seat F model.

The Navy's initial order for the Super Hornet came in 1992, which began the development of the new aircraft. After rigorous test and evaluation, the Super Hornet made its first flight in November 1995 and entered service in 1999 (Boeing, n.d.a). The initial operational Super Hornet squadron, Strike Fighter Squadron 115, executed the first combat deployment in July 2002 (USN, 2009). Since this time, the Navy has outfitted 10 carrier airwings with the Super Hornet, providing the backbone of tactical carrier aviation. The Navy's future plans include purchasing more than 100 additional Super Hornets to complement its approximately 550 existing airframes, thereby ensuring the production lines for supplies and sustainment remain open for many years to come (Trevithick, 2018).

According to Boeing, "the Super Hornet is the most cost-effective aircraft in the U.S. tactical aviation fleet, costing less per flight hour than any other tactical aircraft in U.S. forces inventory" (Boeing, n.d.a). The Super Hornet is pictured in Figure 9.

Source: N. Young (email to author, November 17, 2017).

Figure 9. F/A-18E Super Hornet

C. F-35C LIGHTNING II

1. Mission

"The F-35 Lightning II is a 5th Generation fighter, combining advanced stealth with fighter speed and agility, fully fused sensor information, network-enabled operations and advanced sustainment" (Lockheed Martin, n.d.a).

2. History

After an intense round of competition with Boeing, Lockheed Martin was awarded a contract in 2001 to develop the next generation stealth fighter to complement the Department of Defense's (DoD) arsenal of jet aircraft. This aircraft was designed in a joint manner to satisfy the needs of United States Air Force, United States Marine Corps, and the United States Navy, as well as our international partners and allies. This collaborative effort produced the more commonly used name Joint Strike Fighter (JSF), which is used interchangeably with Lightning II. To fulfill this requirement, three variants were created, all of which are single-seat: F-35A conventional takeoff and landing, F-35B short takeoff vertical landing, and F-35C carrier variant.

> The variation between models allows military forces to achieve service-specific mission capability, while still taking advantage the economies of scale that result from the parts and processes that are common to all three variants. All three variants are supersonic, low observable stealth fighters that all have the same advanced avionics required to execute multirole missions and the support of the F-35 sustainment technologies. (Lockheed Martin, n.d.b)

The Navy's F-35C, seen in Figure 10, is differentiated by larger wings and more robust landing gear, making it suitable for catapult launches and carrier-arrested landings. Additionally, it has the largest internal fuel capacity of the three variants with the capability to inflight refuel (Lockheed Martin, n.d.b).

Lockheed Martin employed an incremental development production plan by first producing the F-35A, followed by the F-35B, and then the F-35C. According to the manufacturer's website, the first flight of the F-35C was on June 6, 2010, four years after the first F-35A flight (Lockheed Martin, n.d.c). This same website indicated this first flight was followed a year later by the first test catapult launch on July 27, 2011, at Joint Base McGuire-Dix-Lakehurst, New Jersey. On June 22, 2013, the first F-35C was delivered to Eglin Air Force Base for United States Navy pilot and maintainer training (Lockheed Martin, n.d.c). The DoN plan is to have the F-35C integrated into all carrier airwings (USN, 2019) with a total procurement of 260 F-35Cs (Lockheed Martin, n.d.b). As of December 2018, Strike Fighter Squadron 147 has received the only safe for flight certification for an operational squadron (Faram, 2018).

Two F-35Cs shown with F/A-18E for size comparison.

Figure 10. F-35C Lightning II. Source: Russell (2015).

D. FOREIGN MILITARY SALES

> Foreign Military Sales (FMS) is the U.S. Government's program for transferring defense articles, services, and training to our international partners and international organizations. The FMS program is funded by administrative charges to foreign purchasers and is operated at no cost to taxpayers. The Defense Security Cooperation Agency (DSCA) administers the FMS program for the Department of Defense (DoD).
>
> Under FMS, the U.S. government uses DoD's acquisition system to procure defense articles and services on behalf of its partners. Eligible countries may purchase defense articles and services with their own funds or with funds provided through U.S. government-sponsored assistance programs. (Defense Security Cooperation Agency, n.d.)

FMS provides numerous benefits to the United States government, DoD, and the DoN. Conducting these transactions creates lasting partnerships with our allies that strengthens regional security, enhances interoperability among the armed forces, and creates economies of scale when combined with United States acquisitions (Obama, 2014). Additionally, the DoD Financial Management Regulation stipulates that FMS transactions will also be priced in a manner to recoup a portion of the research and development (R&D) costs associated with the acquired equipment (Department of Defense [DoD], 2017). Oftentimes, the equipment being acquired is also a current asset of the DoD, which means the concerned Service is repaid for a portion of its own R&D. This R&D frequently is used for future upgrades to existing equipment, providing an extremely valuable benefit for the Service.

While these FMS benefits are extremely valuable, most are difficult to quantify. For example, it is not likely that someone could determine the monetized value of increased regional security that results from one country ordering 80 F-35s. Also, interoperability between partner nations provides the warfare commanders with a distinct advantage over adversaries that cannot be monetized. However, one tangible benefit arises from a decrease in the unit cost per aircraft resulting from increased sales. The problem is that each contract for foreign sales is different. It is not possible to generalize the effects of one nation's procurement and apply that savings to all future sales. Once a contract is written with a foreign nation, the terms of the deal are finalized, and the United States will combine its procurement with the FMS to achieve a total decrease in unit cost for all aircraft involved in that specific contract.

E. KEY INFLUENCER PROGRAM

In addition to cited NFDS source material, the authors rely on their personal knowledge of Blue Angel policies and procedures based on both authors being members of the Blue Angels from 2011–2014. This information is relied on throughout the Key Influencer (KI) and Media Flight portions of this CBA.

At each show site, the Blue Angels conduct a program known as the KI program. This program is governed by the Chief of Naval Air Training (CNATRA). A KI is a person CNATRA deems as influential and

> help [s] to shape attitudes and opinions of recruiting age youth in their communities. The ultimate goal of the Blue Angels Key Influencer Program is to promote a culture of excellence within the community and inspire youth to work hard towards achieving their goals. Deserving candidates, in cooperation with media presence, will promote the Navy and Marine Corps as professional and exciting organizations with which to serve. (Navy Flight Demonstration Squadron [NFDS], 2019, p. 36)

Typical candidates include police officers, firefighters, teachers, youth sports coaches, Boy Scout troop leaders, professional athletes, celebrities, etc. The expectation is that each of these KIs has current and continuing interaction with youth, and their experience with the Blue Angels will be shared in a positive manner.

The KI flights are conducted by Blue Angel #7, the advanced detachment pilot and narrator, on the day of his arrival at the show site. These flights are approximately one hour in length and demonstrate the capabilities of the aircraft and the pride and professionalism of naval aviation. The flights are conducted in the presence of local media outlets to ensure widest dissemination. The flight is performed in one of the NFDS's two-seat F/A-18B/D aircraft.

F. MEDIA FLIGHTS

In addition to CNATRA's KI program, the Blue Angel Public Affairs Office also manages a media flight program. At each show site, one media rider is selected to receive a flight with Blue Angel #7 in the two-seat aircraft. "Media nominations should be from a main stream, well known, accredited organization" and cover the KI's experiences as well as their own flight (NFDS, 2019, p. 38).

G. RECRUITING LEADS

As stated in the Blue Angels' mission statement, an objective of the organization is to inspire service to country. One way to quantify this is through increased recruitment to the Armed Forces. A previous Naval Postgraduate School thesis conducted by Fields, Gardner, and Cousino in 2012 discussed the value of recruiting leads to the Navy. In their study, they determined "the Navy has applied a monetary value of at least $430 for each recruiting lead in support of meeting annual recruiting goals" (p. 21). They determined this value by assuming that 6 percent of all recruiting leads will sign an enlistment contract with the Navy. Using fiscal year (FY) 2009–2011 data, they took the total number of enlistment contracts signed and divided this number by 6 percent to estimate the total number of recruiting leads experienced by the Navy Recruiting Command. As an example, in FY09 they noted 35,527 contracts were signed. Using the 6 percent conversion rate, they calculated 592,117 (35,527/0.06) estimated recruiting leads. Next, they determined the value of a recruiting lead by dividing the total recruiting and advertising budget of the Navy by the estimated number of recruiting leads. Again, using FY09 as an example, they computed this value to be approximately $430 ($256,792,000/592,117). This valuation is used in our data analysis to help quantify the benefits of the KI program.

III. METHODOLOGY

Before analyzing the data, it is beneficial to understand the model to be used. This section will first describe the generic cost benefit analysis methodology and then tailor it to the specifics of this project. This will include narrowing the scope of the analysis and identifying the cost and benefit categories. Lastly, all applicable assumptions are presented and justified.

A. COST BENEFIT ANALYSIS MODEL

Aging airframes and a non-existent supply system have forced the Navy to make a decision regarding the future aircraft of the Blue Angels. Both the Super Hornet and the Lightning II provide suitable platforms for the Blue Angels to conduct their mission; however, a decision must be made between the two, each with its own advantages and disadvantages.

According to the Government Accountability Office (GAO), the DoD has a poor track record when dealing with execution of public funds across the acquisition spectrum (Government Accountability Office, 2017). The overarching purpose of a CBA is to guide social decision-making and make it more rational. Conducting a CBA helps decision makers, whether in the DoD or civilian organizations, make informed decisions about whether or not to pursue a project. By comparing the expected costs with the expected benefits of a project, decision makers are provided with a tool for analysis to support their choice.

In general, three types of CBAs exist. The first is ex ante, which is conducted while a project is still being considered. "*Ex ante* CBA assists in the decision about whether resources should be allocated by government to a specific project or policy or not" (Boardman, Greenberg, Vining, & Weimer, 2017, p. 3). The second CBA is ex post. This analysis is conducted upon completion of a project, when all the costs are "sunk," meaning they have already been incurred in the project. Ex post "contribute to 'learning' by government managers, politicians, and academics about whether particular classes of projects are worthwhile" (Boardman et al., 2017, p. 3). Lastly, an in medias res CBA is conducted during the course of a project. This study is useful to help determine whether or not to continue the project (Boardman et al., 2017).

As of December 2018, the Navy has begun to look into the feasibility of transitioning the Blue Angels to the Super Hornet. Initial modification costs have been proposed by Naval Air Systems Command (NAVAIR) engineers; however, no modifications or flight testing has occurred. In this light, the Super Hornet portion of this project will be conducted in medias res. The F-35C is not being considered for the Blue Angels at this time, therefore, the F-35C portion of this project will be conducted ex ante.

1. History of CBA

CBA use in the United States can be traced back to the 1930s. One of the earliest examples is the Flood Control Act of 1936, which required the use of the United States Army Corps of Engineers to conduct CBAs in their projects (Boardman et al., 2017).

> The U.S. federal government first mandated the general use of CBA in Executive Order 12291, issued by President Reagan in early 1981. This order requires a regulatory impact analysis (RIA) for every major regulatory initiative. (An RIA is essentially a cost-benefit analysis that also takes into account distributional and fairness considerations.). President Clinton confirmed the federal government's commitment to CBA in Executive Order 12866 in 1994. Quite a few U.S. federal laws, such as the Unfunded Mandates Reform Act and the Government Performance and Results Act, specifically mandate some form of *ex ante* analysis. (Boardman et al., 2017, pp. 20–21)

2. Steps of CBA

According to Boardman et al. (2017), there are nine steps to conduct a CBA, as seen in Table 1. It is important to note that as a governmental agency, DoN CBAs must also be conducted in accordance with the Office of Management and Budget (OMB) Circular A-94 (Office of Management and Budget [OMB], 1992).

Table 1. The Steps of a CBA. Adapted from Boardman et al. (2017).

a.	Specify the set of alternative projects.
b.	Decide whose benefits and costs count (standing).
c.	Identify the impact categories, catalogue them, and select measurement indicators.
d.	Predict the impacts quantitatively over the life of the project.
e.	Monetize (attach dollar values to) all impacts.
f.	Discount benefits and costs to obtain present values.
g.	Compute the net present value of each alternative.
h.	Perform sensitivity analysis.
i.	Make a recommendation.

a. Specify the set of alternative projects

When decision makers are faced with conducting a new project, there are oftentimes several courses of action to consider. It is crucial for the evaluator to know all possible alternatives to decisively make a determination (Boardman et al., 2017). This work involves the Navy's choice between two alternative courses of action, the F/A-18 Super Hornet or the F-35C Lightning II. The status quo (i.e., continued operation of the Legacy Hornet) is not a sustainable alternative due to reasons previously discussed.

b. Decide whose benefits and costs count (standing)

This step involves determining whose costs and benefits should be considered when conducting the analysis. For example, the decision to construct a new bridge not only affects the local residents, but adjacent municipalities may benefit from the additional transportation opportunity. Additionally, construction costs may be provided through state or federal grants, creating transfers of benefits. Historically, the federal government takes only national costs and benefits into account (Boardman et al., 2017). In our project, only the costs and benefits of the Navy are considered, as that is the organization to be responsible for implementing and sustaining the Blue Angels. NFDS is not given standing because they are not responsible for making the decision regarding the aircraft; they simply execute the assigned mission.

c. Identify the impact categories, catalogue them, and select measurement indicators

Step three involves determining which factors are a cost or benefit of the proposed alternative. Each factor needs to be grouped as either a cost or benefit, and then it must be determined how to measure those indicators. It is important to only identify those factors that affect the organization with standing, as determined in step 2 (Boardman et al., 2017). Additionally, Boardman et al. state the impact must have value to human beings to be counted. When determining how measure the indicators, the ease of monetization must be considered. Boardman et al. continue that "in order to treat something as an impact, we have to know there is a cause-and-effect relationship between some physical outcome of the project and the utility of human beings with standing" (p. 8). In general, the costs of procuring, modifying, and operating the Super Hornet and Lightning II will be compared to the benefits of their associated use to the Navy. Each of these costs and benefits will be detailed in subsequent chapters.

d. Predict the impacts quantitatively over the life of the project

This step involves looking at each cost and benefit and determining how they will manifest over the life of the project. Some impact categories will only occur at one specific point in time (e.g., aircraft procurement is a one-time upfront cost). Other impact categories occur continuously over the life of the project (e.g., the benefits from the KI flight program will be received every year of Super Hornet operation). Again, each of these costs and benefits will be detailed in subsequent chapters.

e. Monetize (attach dollar values to) all impacts

In this step, each cost and benefit should have a dollar figure assigned to it. This provides a commonality among all costs and benefits so they can be properly compared. Historically, this is one of the most difficult portions of a CBA due to the fact that many variables are not easily monetized (e.g., how much is a media flight worth at each airshow)

(Boardman et al., 2017). A monetized value is typically analogous to willingness to pay. If a consumer market exists for the product, a value can easily be determined from the demand curve. However, in the absence of such a market, careful deliberation must be used to estimate the monetized value of the impact (Boardman et al., 2017).

f. Discount benefits and costs to obtain present values

Any project that lasts more than a year will have costs and benefits that arise in numerous time periods. To properly compare the monetized value of these costs and benefits, it is imperative to discount them to a common time period, usually the beginning of the project (Boardman et al., 2017). This results in the present value (PV). The time value of money, means that a dollar today is worth more than a dollar tomorrow. For this reason, Boardman et al. illustrates all costs and benefits are discounted to the present time according the following formulas:

$$PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t}$$

$$PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t}$$

The first formula represents the present value of benefits (PV(B)), while the second formula provides the present value of costs (PV(C)). In each formula n represents the number of years of life of the project, and B_t and C_t is a cost or benefit occurring in year t. Lastly, r is the social rate used to discount the impact to the present time. This discount rate varies according to the project and the organization involved. "For government analysts, the discount rate is usually mandated by a government agency with authority (e.g., the Office of Management and Budget, or the General Accountability Office in the U.S., or the Ministry of Finance or the Treasury Board)" (Boardman et al., 2017, p. 12). For this project, the OMB mandated discount rate of 7 percent is used (OMB, 1992). The effects of this rate will be addressed in the sensitivity analysis portion of our project.

g. Compute the net present value of each alternative

The present value of all costs is subtracted from the present value of all benefits to yield the net present value (NPV) (Boardman et al., 2017).

$$NPV = PV(B) - PV(C)$$

When analyzing a single alternative, the choice should be accepted if the NPV is positive (i.e., the benefits outweigh the costs):

$$PV(B) > PV(C)$$

However, when more than one alternative is available, generally the choice with the largest NPV should be accepted. It is important to note that the largest NPV among the alternatives available will produce the most efficient result among those analyzed. However, there is no guarantee this is the most efficient solution overall to the project because the NPV only measures the alternatives actually analyzed. "Cognitive capacity limitations, often summarized as bounded rationality problems, may have hindered the analyst from considering the optimal alternative" (Boardman et al., 2017, p. 14).

h. Perform sensitivity analysis

The purpose of sensitivity analysis is to acknowledge uncertainty (Boardman et al., 2017). Some uncertainty is bound to occur in any project. Sensitivity analysis allows the user to modify assumptions one at a time in order to see their effect on the outcome. Boardman et al. indicate some examples can include uncertainty in the monetized value of impacts, the appropriate social discount rate used, and the applicable level of standing.

i. Make a recommendation

While choosing the alternative with the largest NPV is generally the safest course of action for any project, there may be times when this is not the case. For one reason, NPVs are only estimated values based off of inputs with uncertainty. Additionally, there may be external factors to the analysis that could force decision makers to a less suitable alternative (e.g., Congressional pressure). In a hypothetical scenario, we could say that Navy leadership wishes for the Blue Angels to function no matter the cost. When analyzing the choice of aircraft, both alternatives may yield a negative NPV. However, one of the negative alternatives will still be chosen because the Navy has already determined it is willing to bear the costs. It is the responsibility of the CBA analyst to study the alternatives and provide an educated recommendation to decision makers, while also acknowledging the limitations of the study.

B. SCOPE

Since 1946, the DoN has continued to invest resources in the Blue Angels to demonstrate their capabilities to millions of spectators all over the world. The NFDS has remained a priority for Navy leadership throughout the years. As such, the Navy remains dedicated to committing limited resources to the continued operation of the Blue Angels. Because of this, the Navy has a vested interest in how the Blue Angels will continue into the future. The decisions regarding future aircraft will directly affect the Navy's resources as it will be the Navy's budget that is responsible for paying the costs associated with the aircraft. As a result, the Navy is the primary stakeholder in this CBA.

The authors of this project elected to not give NFDS standing in this CBA because the Blue Angels simply receive an annual budget to accomplish its mission with its current aircraft. The squadron's budget is not responsible for capital investments, such as new aircraft, nor does the NFDS leadership have the authority to make the decision to transition aircraft.

Table 2 and the following two subsections detail all of the costs and benefits that will be analyzed for each alternative.

Table 2. Impact Categories for Analysis

Costs	**Benefits**
Aircraft Procurement	Foreign Military Sales
Aircraft Modification	Key Influencer Program
Flight Testing	Media Flights
Normal Operations	

1. Costs

For the purposes of this CBA, the following costs were analyzed for each aircraft: aircraft procurement, aircraft modification, flight testing, and normal operation.

a. Aircraft procurement

One of the largest costs associated with transitioning to a new aircraft is the actual procurement costs. These costs are typically upfront and are intended to provide benefit over the life of the project. The unit costs for each aircraft in both of our alternatives are the baseline costs using current data. These figures are subject to change as the manufacturer's production lines mature. Economies of scale will also enable reduced procurement costs.

b. Aircraft modification

Prior to being utilized in a Blue Angels' aerial demonstration, fleet aircraft must undergo an airframe modification process to allow it to safely execute the demanding maneuvers performed by NFDS pilots. Some of these modifications include the installation of a smoke generating system, inverted fuel pumps, and an artificial feel mechanism, as well as the iconic blue and gold paint scheme. The monetized value of aircraft modification is based off actual data from a contract awarded to Boeing Corporation on August 13, 2018 (DoD, 2018). However, the monetized value of the man-hours required to install the modification kits is based off historical data from Legacy Hornet installations provided by NAVAIR personnel.

c. Flight testing

Whenever a modification is installed on a fleet aircraft, NAVAIR engineers are required to conduct test and evaluation to ensure its safe operation. As a result, the numerous modifications proposed for the Super Hornet or Lightning II will require significant testing. In addition, every maneuver of the NFDS flight demonstration must be tested for suitability in the new airframe. Historically, the cost for every test flight hour has been greater than that of normal operation.

d. Normal operation

Normal operation of each aircraft is combined into an all-encompassing term called "cost per flight hour." This figure is composed of fuel costs, aviation depot level repairs (AVDLR), replacement consumable parts, and various depot maintenance costs. The cost per flight hour is the standard cost to operate an aircraft from a typical Navy fleet squadron.

e. Security requirements

Security for the Blue Angels' aircraft is provided by each show site (Navy Flight Demonstration Squadron, 2019). The security requirement for the Super Hornet is the same that the Blue Angels currently require for their Legacy Hornet. However, the F-35C is classified at a higher level. This increased classification level represents an increase in the security requirements. The security required to meet the higher classification level when the aircraft is not in use by Blue Angel personnel (i.e., overnight parking), has yet to be determined by DoD security agencies. It is also unknown whether this increased security presence will be paid for by the show or the NFDS. Due to the myriad unknowns regarding the enhanced security, this cost will not be considered in this CBA. If it is later determined that this represents a cost to the NFDS, it will need to factored into the data analysis.

2. Benefits

For the purposes of this CBA, the following benefits were analyzed for each aircraft: foreign military sales, key influencer program, and media flight program.

a. Foreign military sales

As more of our global partners and allies place orders for the Super Hornet and Lightning II, the individual unit cost will decrease. This will directly contribute to cost savings for future purchases by the DoN. As previously stated, the savings per aircraft resulting from an FMS contract cannot be generalized to show the future value of all foreign sales. Therefore, this CBA model will examine the effects of one FMS contract to quantify its benefits. The authors acknowledge the limitations of this data on the outcome of the CBA. The contract data is provided to show a single example of potential future FMS benefits.

b. Key influencer program

The KI program described previously is a unique benefit provided to the Navy by the Blue Angels. When a KI shares their experience with the local community, the youth form a favorable impression of the Navy, which often materializes into a recruiting lead. This recruiting lead has a monetized value and benefit previously introduced in this study.

c. Media flights

Media flights serve a similar purpose to the KI program. These flights also serve to provide exposure to naval aviation; however, the focus of these flights is more towards marketing and advertising at the current show site. In lieu of paid advertisements by the Navy, the media rider will produce a story to be covered by their media station, which not only shares their experience, but also attracts more spectators to attend the show. The costs saved by not paying for marketing and advertising at each show site are a benefit to the Navy.

C. ASSUMPTIONS

In conducting this analysis, three significant assumptions were made to develop a model on which to base our recommendation. The assumptions are based on several factors from the authors' corporate knowledge of naval policy, Blue Angel policy, and manpower distribution.

First, if the Blue Angels transition to the Super Hornet, the switch will be accomplished using existing aircraft already owned by the Navy. The justification behind this assumption lies in the fact that this is the current modus operandi of the Blues. There are two major components in determining the service-life of a naval aircraft. The first is the flight hours remaining on the airframe, as determined by NAVAIR engineers and Boeing designers. The second is the number of carrier-arrested landings (i.e., traps) remaining on the airframe. Due to the nature of naval deployments, a typical carrier-based aircraft will reach the end of its service life via the number of traps left long before it runs out of flight hours. Because the Blue Angels do not conduct deployments aboard aircraft carriers, the squadron can continue to fly aircraft that are not useful to the regular fleet.

Despite being newer, there is already a very large number of Super Hornets that have reached their maximum trap count. These aircraft can easily be allocated to the Blues without incurring procurement costs. On the other hand, the Navy currently owns only 16 F-35Cs (Lockheed Martin, n.d.a). The inventory of F-35Cs is not sufficient to support an initial outfitting for the Blue Angels. Therefore, these aircraft would need to be procured from Lockheed Martin.

The second assumption is the cost to train pilots and maintainers to operate the Super Hornet will not be a factor. This is validated in a couple of ways. First, there is already an extremely large pool of naval aviators and maintenance personnel who are already fully qualified in the Super Hornet. The squadron can easily be manned from this existing group of people without additional costs. Furthermore, the Navy currently allows both pilots and maintainers to simultaneously hold active qualifications in the Legacy Hornet and Super Hornet, which will aid in the transition. Finally, the current manning doctrine of the Navy freely switches personnel from Legacy squadrons to Super Hornet squadrons while conducting routine PCS moves. In other words, if a Sailor is currently attached to a Legacy squadron with all of its associated qualifications, that Sailor can also expect to be detailed to a Super Hornet squadron with his next set of orders. Although the F-35C community is relatively new in the Navy, the number of qualified pilots and maintainers will continue to expand, providing a similar group of candidates as the Super Hornet. Existing Hornet qualified personnel are expected to be able to transition to the F-35C in a similar manner as from the Legacy Hornet to the Super Hornet. Due to the infancy of the F-35C community, the authors expect this assumption to be challenged in the future. No transition costs will be associated with this analysis.

Finally, all costs and benefits are assumed to occur at the end of each time period when calculating the overall NPV of each impact category.

A summary of assumptions is provided in Table 3.

Table 3. Assumptions Used in CBA

1.	COA 1 will not require procurement of new Super Hornets.
2.	Pilot and maintenance crew training will not be a factor.
3.	Costs and benefits occur at the end of each time period.

IV. COA 1: F/A-18 SUPER HORNET

A. COSTS

1. Aircraft Procurement

Although this project is assuming that the DoN will not procure new Super Hornets for the Blue Angels, it is worth noting the most up to date cost. This figure could prove to be relevant for future studies, or it can be quickly referenced if the Navy elects to provide the Blue Angels with new Super Hornet aircraft. Additionally, this value will be used later in this study to provide an estimate for the modification cost for the F-35C.

On August 13, 2018, the DoD awarded a firm-fixed price contract to Boeing Corporation "for the retrofit documentation and kits to convert nine F/A-18E and two F/A-18F aircraft into a Blue Angel configuration in accordance with engineering change proposal 6480" (DoD, 2018). In awarding this contract, the DoN has established that the squadron will be initially outfitted with a total of 11 aircraft, with nine aircraft being the single-seat variant and two aircraft being the two-seat variant.

The President's Budget for FY2019 established the flyaway unit cost of an F/A-18 Super Hornet as $68,643,542 (FY19) (Department of the Navy, 2018). The total aircraft acquisition cost would then be **$755,078,962 (FY19)** ($68,643,542 x 11). The flyaway cost represents the cost for an aircraft fully equipped with all guidance, propulsion, airframe, and avionics systems. Other programs costs (e.g., support equipment, training, spares, publications, normal operations, etc.) are ignored since this program is already well-established in the Navy and would not need to be procured in this instance.

Aircraft procurement data is summarized in Table 4.

Table 4. Aircraft Procurement Data Summary

Number of Required Aircraft	11
Cost per Aircraft	$68,643,542 (FY19)
Total Aircraft Procurement Cost	**$755,078,962 (FY19)**

2. Aircraft Modification

The previously discussed contract with Boeing in August 2018 totaled $17,002,107, using FY18 aircraft procurement funds for the 11 aircraft (DoD, 2018). To adjust from FY18 to FY19 dollars, the Naval Center for Cost Analysis' Joint Inflation Calculator (JIC) was used with the Aircraft Procurement Navy (APN) Index, resulting in $17,342,149. This equates to a price of $1,576,559 per aircraft. This cost represents only the physical parts necessary to complete the modification.

To determine the man-hours required to install the modification kit, data from the PMA265 F/A-18A-D Air Vehicle PM Lead Specialist was used (Turner, email to author, January 2, 2019). According to this specialist, 1,950 man-hours are used to complete the Legacy Hornet modification at an average cost of $200 (FY19) per man-hour. Additionally, the Super Hornet is approximately 25 percent larger than the Legacy Hornet (Boeing, n.d.b). The authors assume this 25 percent increase in size will directly translate to a 25 percent increase in man-hours required to modify the larger Super Hornet aircraft. This results in approximately 2,438 (1,950 x 1.25) man-hours to modify the Super Hornet aircraft. Therefore, labor cost to install the modification kits for the Super Hornet is approximately $487,500 (FY19) ($200 x 2,438) per aircraft. Accounting for all 11 squadron aircraft results in a total cost of $5,362,500 (FY19) ($487,500 x 11).

In addition to the airframe modification kit, a specialized Blue Angel paint scheme is applied to each aircraft. From the PMA265 specialist, the Blue Angel paint scheme is comprised of several 55 gallons of paint requiring 1,242 man-hours (email to author, January 2, 2019), as shown in Table 5.

Table 5. Blue Angel Legacy Hornet Paint Scheme Composition

Color of Paint	Cost (FY19$)
15 Gallons of Primer	$6,000
15 Gallons of Blue	$4,950
4 Gallons of Yellow	$2,780
5 Gallons of White	$1,650
16 Gallons of Clear	$3,520
1,242 Man-hours at $200 per hour	$248,400
Total Cost per aircraft (man-hours + material)	$267,300

Again, assuming the larger aircraft will result in a 25 percent increase in material and costs, Table 6 depicts the proposed Super Hornet paint scheme.

Table 6. Blue Angel Super Hornet Paint Scheme Composition

Color of Paint	Cost (FY19$)
18.8 Gallons of Primer	$7,500
18.8 Gallons of Blue	$6,188
5 Gallons of Yellow	$3,475
6.3 Gallons of White	$2,063
20 Gallons of Clear	$4,400
1,553 Man-hours at $200 per hour	$310,600
Total Cost per aircraft (man-hours + material)	$334,226
Total Cost for 11 aircraft	$3,676,486

The aircraft modification cost for the Super Hornet will be the total price of the modification kit, labor hours for installation, and the updated Blue Angel paint scheme with man-hours included. This total equates to **$26,381,135 (FY19)** ($17,342,149 for modification kit, $5,362,500 for labor hours of installation, and $3,676,486 for paint scheme update).

Aircraft modification data is summarized in Table 7.

Table 7. Aircraft Modification Data Summary

Modification Kit Cost	$17,342,149 (FY19)
Kit Installation Cost	$5,362,500 (FY19)
Paint Material Cost	$259,886 (FY19)
Paint Installation Cost	$3,416,600 (FY19)
Total Aircraft Modification Cost	**$26,381,135 (FY19)**

3. Flight Testing

As a baseline, it is assumed that the Super Hornet will require 100 hours of flight testing after modifications have been installed to verify its air worthiness. According to NAVAIR engineers, the most recent F/A-18E/F Super Hornet cost per flight test hour is $28,650 (FY18). Again, using the JIC's APN index, this value is adjusted to $29,223 (FY19). Therefore, the total flight test cost would be **$2,922,300** ($29,223 x 100).

Flight test data is summarized in Table 8.

Table 8. Flight Test Data Summary

Number of Required Flight Test Hours	100
Cost per Flight Test Hour	$29,223 (FY19)
Total Cost for Flight Testing	**$2,922,300 (FY19)**

4. Normal Operations

The cost per flight hour for normal operations is a figure that represents the average cost to operate the aircraft for one hour of flight. Numerous inputs are factored in to this value to provide a budgeting tool for squadrons. Examples of associated components are average cost of fuel consumed per flight hour, average cost of parts that must be replaced due to unforeseen malfunctions, pre-determined depot-level maintenance, and consumables (e.g., tires, oil, lubricants, etc.). To determine the cost per flight hour, the Under Secretary of Defense (Comptroller) Memorandum on Fiscal Year 2019 Department of Defense Fixed Wing and Helicopter Reimbursement Rates was referenced. According to this document, the average cost per flight hour for an F/A-18E is $11,828 and F/A-18F is $12,475 (McAndrew, 2018). The average of the two figures will be used for this CBA: $12,152 (FY19).

To project the total cost of normal operations, it is necessary to estimate the useful life of the Super Hornet in the Blue Angels. Because the Legacy Hornet has been flown by the squadron for just over 30 years (since 1986), the authors will assume that the Super Hornet will have a similar lifespan and be flown by the Blue Angels for 30 years. Therefore, the normal operating cost of the Super Hornet will be spread over that 30-year period. According to the 2019 Blue Angels' Operations Officer, LCDR Brandon Hempler, (email to author, January 17, 2019), the Blue Angels fly approximately 3,200 Legacy Hornet flight hours per calendar year. Using 3,200 hours per year, the annual normal operating cost would be $38,886,400 (FY19) ($12,152 x 3,200). In order to calculate the net present value of the 30-year normal operating cost, it is necessary to assume the cost per flight hour and annual hours flown will remain constant. Using this logic, the NPV of the normal flight hour cost is calculated as a 30-year annuity with CF representing the annual operation cost, r representing the OMB discount rate, and t representing the 30-year life of the aircraft (Brealey, Myers, Allen, & Mohanty, 2014):

$$NPV = \frac{CF}{r} * [1 - \frac{1}{(1+r)^t}]$$

$$NPV = \frac{\$38{,}886{,}400}{.07} * \left[1 - \frac{1}{(1+.07)^{30}}\right] = \$482{,}542{,}939$$

The results above indicate that the normal cost of operating the F/A-18E/F Super Hornet over a 30-year lifespan will cost approximately **$482,542,939 (FY19)**.

Normal operations data is summarized in Table 9.

Table 9. Normal Operations Data Summary

Expected Lifespan of COA	30 years
Cost per Flight Hour	$12,152 (FY19)
Annual Flight Hours	3,200
Annual Operating Cost	$38,886,400 (FY19)
Discount Rate	7%
NPV of 30-year Normal Operation	**$482,542,939 (FY19)**

B. BENEFITS

1. Foreign Military Sales

For this CBA model, potential FMS benefits for the F-18E/F are being monetized based off the most recent contract awarded to Boeing. Due to proprietary information, actual country names will be withheld from the discussion. According to the PMA-265 FMS Lead Cost Analyst, 28 aircraft were requested by a foreign country. When combined with the DoN's procurement of 18 Super Hornets over the same timeframe, the resulting savings for the DoN was **$5,724,000 (FY19)** (C. Hickman, email to author, February 11, 2019).

Foreign military sales data is summarized in Table 10.

Table 10. FMS Data Summary

Foreign Aircraft Procured	28
Savings per DoN Aircraft	$318,000 (FY19)
Number of DoN Aircraft	18
Total DoN Savings	**$5,724,000 (FY19)**

2. Key Influencer Program

As previously described, the key influencer program is designed to provide influential community leaders with a flight in a Blue Angel aircraft. The expectation is that this person will share their experience with potential future recruits for the Armed Forces. In the background and literature review chapter, the study conducted by Fields, Gardner, and Cousino (2012) provided an estimate for the value of a recruiting lead, $430 (FY09). A recruiting lead was defined as someone with the potential to sign an enlistment contract with the Armed Forces.

For this CBA, actual data from the author's flight logbook from the 2011 Blue Angels show season was utilized to determine the number of KIs that were flown by the Blue Angels that year. In total, 70 key influencers were flown at 31 show sites. From the 70 key influencers, the authors deemed six individuals as having an influence outside of their local area, i.e., a celebrity. The importance of this distinction is that these six people are able to have an influence over a much larger number of potential recruiting leads than a normal key influencer. The authors assume that a regular key influencer will have the ability to impact approximately 250 potential recruiting leads by sharing their experience with the Blue Angels. Furthermore, the authors assume that a celebrity key influencer has the ability to inspire 10,000 potential recruiting leads through social media and other avenues.

With 64 normal key influencers reaching 250 people each and six celebrity key influencers reaching 10,000 people each, the total annual recruiting leads from this source is 76,000 (64 x 250 + 6 x 10,000). If each recruiting lead is valued at $430 (FY09), the total recruiting benefit per year is $32,680,000 (FY09) (76,000 x $430). Converting this value to FY19 dollars using the APN index yields $38,223,135 (FY19). Additionally, the duration of each KI flight is approximately one hour. Using the $12,152 (FY19) cost per flight hour from above, the total cost to conduct the KI program is $850,640 ($12,152 x 70 flights). When this cost is subtracted from the recruiting benefit, the net benefit for the KI program for one year is $37,372,495 (FY19). Assuming the KI program continues over the 30-year life of the Super Hornet with the same number of key influencers per year, the NPV of the benefit of the KI program is calculated using the same formula given above:

$$NPV = \frac{\$37{,}372{,}495}{.07} * \left[1 - \frac{1}{(1+.07)^{30}}\right] = \$463{,}756{,}830$$

The results above indicate that the benefit of the KI program over a 30-year lifespan will be approximately **$463,756,830 (FY19)**.

Key Influencer program data is summarized in Table 11.

Table 11. Key Influencer Data Summary

Recruiting Lead Value	$503 (FY19)
Annual Recruiting Leads	76,000
Total Annual Recruiting Benefit	$38,223,135 (FY19)
Annual Cost of KI Flights	$850,640 (FY19)
Annual Net Benefit of KI Flights	$37,372,495 (FY19)
NPV of 30-year KI Program	**$463,756,830 (FY19)**

3. Media Flights

The media flight program is designed to provide commercial exposure to the local community in order to attract more spectators to the event. Media flights focus more on advertising and marketing, while the KI program focuses more on recruitment.

The media flights are conducted under the assumption that the rider's experience will receive in-depth coverage at their respective media outlet. If all media riders are television personalities, which typically have larger viewing audiences than other media platforms (Mitchell, Shearer, Gottfried, & Barthel, 2016), the authors assume that each media rider will produce a two-minute segment that would be aired daily on each of the station's news broadcasts. With local news being aired once in the early morning, once at midday, twice in the early evening, and once in the late evening, there are five times a day that the two-minute segment can be aired.

The media flight is typically conducted on a Thursday afternoon, shortly after Blue Angel #7 arrives at a new show site. As a result, the early morning and midday news broadcasts air before the media flight is conducted. With the three remaining broadcasts on Thursday and the five broadcasts Friday, Saturday, and Sunday, there are 18 expected times when the media flight segment is broadcast. These 18 spots equate to 36 minutes of total coverage.

The average 30-second television commercial costs approximately $850 (FY17) (Aland, 2017) or $1,700 per minute. Using this value, the 36 minutes of total coverage per show site described above would cost $61,200 (FY17) ($1,700 x 36 minutes) or $63,797 (FY19). However, this monetary value is viewed as a benefit for the NFDS rather than a cost. The Blue Angels are scheduled to perform at 31 show sites in 2019 (Unites States Navy, n.d.a). Assuming a constant advertising cost throughout the United States, the total benefit of advertising from the media flights is $1,977,707 (FY19) ($63,797 x 31). With a one-hour media flight, the cost to conduct these flights is $376,712 (FY19) ($12,152 x 31). The resulting net benefit of the program is $1,600,995 (FY19) per year. Again, annuitizing this program over the expected 30-year life of the Super Hornet, the NPV of the benefit of the media program is as follows:

$$NPV = \frac{\$1,600,995}{.07} * \left[1 - \frac{1}{(1+.07)^{30}}\right] = \$19,866,813$$

The results above indicate that the benefit of the media flight program over a 30-year lifespan will be approximately **$19,866,813 (FY19)**.

Media Flight program data is summarized in Table 12.

Table 12. Media Flight Data Summary

Expected Show Sites per year	31
Expected Media Coverage per Show Site	36 minutes
Average Commercial Cost per minute	$1,772 (FY19)
Total Media Benefit per Show Site	$63,797 (FY19)
Annual Media Benefit	$1,977,707 (FY19)
Annual Cost of Media Flights	$376,712 (FY19)
Annual Net Benefit of Media Flights	$1,600,995 (FY19)
NPV of 30-year Media Flight Program	**$19,866,813 (FY19)**

C. SUMMARY OF RESULTS

The results of the data analysis for the F/A-18E/F Super Hornet are presented in Table 13. The values indicated as (C) represent a cost, while the values marked as (B) refer to a benefit. The NPV of $-22,498,731 shows that the total costs associated with the F/A-18E/F outweigh the cumulative benefits from its use, from a financial standpoint.

Table 13. Net Present Value of F/A-18E/F Super Hornet

Impact Category	**Monetized Value (FY19$)**
Aircraft Procurement	N/A
Aircraft Modification	$26,381,135 (C)
Flight Testing	$2,922,300 (C)
Normal Operations	$482,542,939 (C)
Foreign Military Sales	$5,724,000 (B)
Key Influencer Program	$463,756,830 (B)
Media Flights	$19,866,813 (B)
Net Present Value (B-C)	**$-22,498,731**

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V. COA 2: F-35C LIGHTNING II

A. COSTS

1. Aircraft Procurement

Due to the low inventory level of F-35Cs in the Navy, it is most likely that new aircraft would need to be purchased in order to outfit the Blue Angels. The President's Budget for FY2019 established the flyaway unit cost of an F-35C Lightning II as $120,992,667 (FY19) (Department of the Navy, 2018). Following the logic from the existing Boeing modification kit contract that the Navy is considering nine single-seat Super Hornets and two two-seat Super Hornets, the authors assume that only nine F-35Cs will be procured for the Blue Angels because a two-seat version does not exist. Therefore, the total aircraft procurement cost would be **$1,088,934,003 (FY19)** ($120,992,667 x 9). Again, only flyaway cost is considered due to the fact that all Navy initial procurement contracts fund required support equipment and spares.

Aircraft procurement data is summarized in Table 14.

Table 14. Aircraft Procurement Data Summary

Number of Required Aircraft	9
Cost per Aircraft	$120,992,667 (FY19)
Total Aircraft Procurement Cost	**$1,088,934,003 (FY19)**

2. Aircraft Modification

Currently, no plans exist to modify an F-35C for use in the NFDS. As a result, no request for proposals has been issued to design a modification kit to accomplish this. In order to estimate an aircraft modification cost for the F-35C, assumptions were made to compare the existing Super Hornet modification cost to one that would be required for the F-35C. The F/A-18E/F modification cost of $2,398,285 (FY19) per aircraft represents approximately 3.5 percent of the total cost of one Super Hornet. Due to a lack of reliable information, the authors will assume that an F-35C modification cost will also represent 3.5 percent of the total cost of one aircraft. Therefore, the per unit modification cost for the F-35C will be $4,234,743 (FY19) ($120,992,667 x 3.5 percent). The total cost for the nine-squadron aircraft would be approximately **$38,112,690 (FY19)**.

Aircraft modification data is summarized in Table 15.

Table 15. Aircraft Modification Data Summary

Number of Required Aircraft	9
Aircraft per Unit Cost	$120,992,667 (FY19)
Modification Cost (3.5% of A/C Cost)	$4,234,743 (FY19)
Total Modification Cost	**$38,112,690 (FY19)**

3. Flight Testing

As a baseline, it is also assumed that the Lightning II will require 100 hours of flight testing after modifications have been installed to verify its air worthiness. According to NAVAIR engineers, the most recent F-35C Lightning II cost per flight test hour is $59,817 (FY19) (J. Piercy, email to author, February 12, 2019). Therefore, the total flight test cost would be **$5,981,700 (FY19)** ($59,817 x 100).

Flight test data is summarized in Table 16.

Table 16. Flight Test Data Summary

Number of Required Flight Test Hours	100
Cost per Flight Test Hour	$59,817 (FY19)
Total Cost for Flight Testing	**$5,981,700 (FY19)**

4. Normal Operations

As previously discussed for the Super Hornet, the cost associated with normal operation of the F-35C is represented in the average cost per flight hour. Again, this value was provided by the Under Secretary of Defense (Comptroller). The average cost per flight hour is $22,978 (FY19) (McAndrew, 2018).

The authors will again assume that the Lightning II will have a similar lifespan to the Legacy Hornet and be flown by the Blue Angels for 30 years. Therefore, the normal operating cost of the Lightning II will be spread over that 30-year period. Referencing the same flight hour data, the Blue Angels fly approximately 3,200 hours per calendar year. Using 3,200 hours per year, the annual normal operating cost would be $73,529,600 (FY19) ($22,978 x 3,200). In order to calculate the net present value of the 30-year normal operating cost, it is necessary to assume the cost per flight hour and annual hours flown will remain constant. Using this logic, the NPV of the normal flight hour cost is calculated as a 30-year annuity with CF representing the annual operation cost, r representing the OMB discount rate, and t representing the 30-year life of the aircraft:

$$NPV = \frac{CF}{r} * [1 - \frac{1}{(1+r)^t}]$$

$$NPV = \frac{\$73{,}529{,}600}{.07} * \left[1 - \frac{1}{(1+.07)^{30}}\right] = \$912{,}431{,}834$$

The results above indicate that the normal cost of operating the F-35C Lightning II over a 30-year lifespan will cost approximately **$912,431,834 (FY19)**.

Normal operations data is summarized in Table 17.

Table 17. Normal Operation Data Summary.

Expected Lifespan of COA	30 years
Cost per Flight Hour	$22,978 (FY19)
Annual Flight Hours	3,200
Annual Operating Cost	$73,529,600 (FY19)
Discount Rate	7%
NPV of 30-year Normal Operation	**$912,431,834 (FY19)**

B. BENEFITS

1. Foreign Military Sales

For this CBA model, potential FMS benefits for the F-35C are being monetized based off the most recent contract awarded to Lockheed Martin. Due to proprietary information, actual country names will be withheld from the discussion. According to the F-35 FMS Program Deputy, 24 aircraft were requested by a foreign country for delivery between 2027 and 2032. When combined with the DoN's procurement of 260 aircraft, the resulting savings for the DoN was **$373,000,000 (FY19)** (R. Wilkerson, email to author, February 7, 2019).

Foreign military sales data is summarized in Table 18.

Table 18. FMS Data Summary.

Foreign Aircraft Procured	24
Savings per DoN Aircraft	$1,434,615 (FY19)
Number of DoN Aircraft	260
Total DoN Savings	$373,000,000 (FY19)

2. Key Influencer Program

All variants of the F-35 are designed to be single-seat aircraft and there are no future plans to modify the aircraft for a two-seat cockpit. As a result, the KI program cannot exist as it currently functions. Therefore, the Blue Angels will realize zero benefit from the KI program if they operate the F-35C.

3. Media Flights

Like the KI program, media flights can only be conducted in a two-seat aircraft. Due to the design limitations discussed above, media personnel will not be able to be flown in a Blue Angel F-35C. Therefore, the Blue Angels will realize zero benefit from the media flight program if they operate the F-35C.

C. SUMMARY OF RESULTS

The results of the data analysis for the F-35C Lightning II are presented in Table 19. The values indicated as (C) represent a cost, while the values marked as (B) refer to a benefit. The NPV of $-1,672,460,227 shows that the total costs associated with the F-35C outweigh the cumulative benefits from its use, from a financial standpoint.

Table 19. Net Present Value of F-35C Lightning II.

Impact Category	Monetized Value (FY19$)
Aircraft Procurement	$1,088,934,003 (C)
Aircraft Modification	$38,112,690 (C)
Flight Testing	$5,981,700 (C)
Normal Operations	$912,431,834 (C)
Foreign Military Sales	$373,000,000 (B)
Key Influencer Program	N/A
Media Flights	N/A
Net Present Value (B-C)	**$-1,672,460,227**

VI. THE FINANCIAL COST BENEFIT ANALYSIS FOR F/A-18 SUPER HORNET VERSUS F-35C LIGHTNING II

Given the comparison of applicable costs and benefits for each COA, presented in the previous chapter, the net present value for each choice was calculated assuming a 30-year service life. The results are shown in Table 20.

Table 20. Comparison of Net Present Values

	F/A-18E/F	**F-35C**
Impact Category	**Monetized Value (FY19$)**	**Monetized Value (FY19$)**
Aircraft Procurement	N/A	$1,088,934,003 (C)
Aircraft Modification	$26,381,135 (C)	$38,112,690 (C)
Flight Testing	$2,922,300 (C)	$5,981,700 (C)
Normal Operations	$482,542,939 (C)	$912,431,834 (C)
Foreign Military Sales	$5,724,000 (B)	$373,000,000 (B)
Key Influencer Program	$463,756,830 (B)	N/A
Media Flights	$19,866,813 (B)	N/A
Net Present Value (B-C)	**$-22,498,731**	**$-1,672,460,227**

The data in this CBA is analyzed from a financial standpoint, meaning that the monetary value of the costs and benefits were compared to each other using their face value. Each impact category was given equal weight in the total comparison.

The Super Hornet's NPV of $-22,498,731 is larger than the Lightning II's NPV of $-1,672,460,227. Generally, the COA with the largest NPV should be accepted. As discussed, however, the NPV values are estimates subject to sensitivity analysis. It is possible that the uncertainty found in the data could alter the course of action with the highest NPV. Additionally, NPVs with a negative value indicate that the costs outweigh the benefits for a particular alternative. Generally, these situations should be avoided from an investment standpoint. However, in this case, one of the negative alternatives can still be chosen because the Navy has already determined it is willing to bear the costs to operate the Blue Angels.

Before discussing specific sensitivity analyses for the two COAs, it is important to note that the chosen discount rate used in conducting any CBA is frequently a source of uncertainty. The chosen discount rate can have significant effects on both costs and benefits depending on when they occur during the COA's duration. However, in this CBA, all costs and benefits are spread evenly throughout the 30-year proposed life of both COAs. As a result, varying the discount rate will change the magnitude of each COA's NPV, but both NPVs will change by the same percentage, thereby maintaining the same proportionality between the two. Therefore, a different discount rate in this analysis will never result in a different COA being chosen, when selected purely from a financial standpoint.

A. SENSITIVITY ANALYSIS FOR COA 1: F/A-18E/F SUPER HORNET

The purpose of the sensitivity analysis is to recognize uncertainty in the CBA model, and the fact that our financial CBA model includes assumptions and data is difficult to estimate with precision and predict with certainty. One of the largest potential issue to this particular analysis concerns the decision for the Navy to use existing Super Hornets for use in the NFDS. The NPV presented in Table 13 represents the net position assuming the Navy adheres to the expected course of action of modifying existing aircraft. If this assumption proves false, the aircraft procurement cost of $755,078,962 (FY19) would need to be added in as a cost, thereby reducing the overall NPV to $-777,577,963, as seen in Table 21. This alternative course of action is presented alongside the proposed course of action to easily compare the difference and appreciate the magnitude of the changes. Although the alternate COA's NPV decreases by $755,078,962 to $-777,577,963, this NPV is still more favorable than the NPV of the F-35C Lightning II ($-1,672,460,227) from a financial perspective. The results of this sensitivity analysis provide Navy leadership will more options to review before determining how to implement the aircraft change.

Table 21. Alternative Course of Action for Super Hornet.

Impact Category	**Proposed (FY19$)**	**Alternate (FY19$)**
Aircraft Procurement	N/A	$755,078,962 (C)
Aircraft Modification	$26,381,135 (C)	$26,381,135 (C)
Flight Testing	$2,922,300 (C)	$2,922,300 (C)
Normal Operations	$482,542,939 (C)	$482,542,939 (C)
Foreign Military Sales	$5,724,000 (B)	$5,724,000 (B)
Key Influencer Program	$463,756,830 (B)	$463,756,830 (B)
Media Flights	$19,866,813 (B)	$19,866,813 (B)
Net Present Value (B-C)	**$-22,498,731**	**$-777,577,693**

Sensitivity analysis allows the user to modify assumptions one at a time in order to see their effect on the outcome. Table 21 depicts the effects of one such variable change. There are several variables that could be altered in this scenario that would each have a different effect on the final NPV. A similar analysis as that seen in Table 21 can be conducted for each of these variable changes. Although each variable change is not presented numerically in this study, short descriptions of a few variables follow.

As previously stated, flight testing is a mandatory requirement whenever modifying any aircraft from its original configuration. 100 hours of flight testing was assumed to be required as a baseline for this analysis. The actual amount of flight testing that will be required to certify the Super Hornet for use in the Blue Angels demonstration will not be known in totality until NAVAIR engineers are satisfied with the results of the tests. Therefore, the cost of flight testing proposed in this project is subject to change.

In determining the benefit of the KI program, the number of potential recruiting leads that were impacted by each KI rider was assumed. Although these numbers are an assumption, the actual values are of little significance, knowing the F-35C has no KI capability. Any number of potential recruiting leads will provide a benefit to the Navy as long as a certain breakeven threshold is met. As calculated, the annual cost to physically fly the KI riders is $850,640 (FY19). If each recruiting lead is valued at $503 (FY19) according to the cited study, the Blue Angels' KI riders would need to impact approximately 1,692 youths each year to break even ($850,640 / $503). If less than 1,692 youths are actually impacted, the KI program would represent a cost to the Navy, rather than a benefit. As the number of impacts increases, the benefit to the Navy also increases.

Additionally, the media flight program has a breakeven point similar to the KI program. Using the cost per flight hour of $12,152 (FY19) and the cost per minute of advertising of $1,772 (FY19), it would require 6.9 minutes of advertising per airshow to breakeven ($12,152 / $1,772). If less than 6.9 minutes of advertising are received, the program would represent a cost to the Navy, rather than a benefit. As the number of minutes of advertising increases, the benefit to the Navy also increases.

B. SENSITIVITY ANALYSIS FOR COA 2: F-35C LIGHTNING II

Due to the hypothetical nature of this analysis, the authors took a great deal of liberty in estimating the aircraft modification costs for the F-35C, to include whether or not a transition is possible. NAVAIR engineers will need to collaborate with Lockheed Martin manufacturers to discuss the possibilities of modifying the aircraft to meet the demonstration's requirements (e.g., smoke tank installation). Because these costs are unknown, the method described in the data analysis section was used as a preliminary estimate. It is likely that the actual value will be higher, resulting in an increased cost.

The same consideration discussed for the number of hours of Super Hornet flight testing applies to the F-35C.

As of the writing of this study, only one operational squadron in the Navy is operating the F-35C. As the Navy's inventory of F-35Cs continues to increase, the supply system will also grow with it. This should serve to drastically reduce the cost of routine and depot-level maintenance, as well as consumable expenses. As a result, it is expected that the cost per flight hour for normal operations will continue to decrease in the coming years.

C. RECOMMENDATION

Given the steps, assumptions, and data we used for this financial CBA, from a financial standpoint, it is the recommendation of the authors that the Navy select the F/A-18E/F Super Hornet to be the next aircraft for the Blue Angels. A few caveats to this recommendation are discussed in the conclusion.

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VII. CONCLUSION

The purpose of this project was to analyze two alternative aircraft choices for the Navy to utilize in the Blue Angels flight demonstration as a replacement for the F/A-18 Legacy Hornet. To accomplish this, a financial CBA model was developed to analyze potential costs and benefits associated with two COAs (F/A-18E/F Super Hornet and F-35C Lightning II) to develop a decision support tool. The costs included in the financial CBA are aircraft procurement, aircraft modification, flight testing, and normal operations. The benefits included are foreign military sales, key influencer program, and media flight program. Although several crucial assumptions and limitations were identified, based on the financial analysis, it is the recommendation of the authors to select the F/A-18E/F Super Hornet for the next Blue Angels aircraft. As with many CBAs, a purely financial analysis may only provide one aspect to be considered before deciding on a COA.

It is worth noting there are some relative strengths of the F-35C that are not fully apparent from a financial standpoint. These strengths provide benefits to the Navy but are difficult to monetize. As an example, currently there are only two countries that are FMS partner nations with the United States for the Super Hornet. According to NAVAIR PMA-265, as of February 2019, there are 52 foreign operated Super Hornets (J. Kennedy, email to author, February 7, 2019). In contrast, there are eight FMS partner nations for the Lightning II in addition to numerous other foreign customers. According to the F-35 FMS deputy, by 2033 there will be 903 foreign operated F-35s (R. Wilkerson, email to author, February 7, 2019). Operating similar equipment as our Allies and partners provides a great deal of joint interoperability that will deliver immeasurable benefits in future conflicts. This significant number of foreign acquisitions will serve to ensure the F-35 production line continues to operate at an efficient level for years to come, enabling sustainment of the aircraft.

The nature of the FMS program creates a significant limitation on the CBA model used in this study. DoN leadership must be aware of the limitations found in the data when using it to make their decision.

Additionally, the first operational Super Hornet squadron was formed in 2001 (Boeing, n.d.a). As of 2019, the Super Hornet has been flying operationally in the Navy for

19 years. While the Super Hornet has become the backbone of the Navy's tactical jet fleet, there is uncertainty regarding how much longer the Navy will continue to procure new Super Hornets. Current funding (as of FY19) is authorized to purchase approximately 24 Super Hornets per year until FY23 (J. Kennedy, email to author, February 12, 2019). Funding beyond FY23 is unknown. While more than 20 years of procurement has created a large inventory of Super Hornets in the Navy, the existing airframes are aging at a rapid pace. A lack of future Super Hornet procurement beyond FY23 will likely cause the production facility to close, unless FMS keeps it going. This CBA model assumed a 30-year life of each COA, but it is possible for the supply system to not be able to sustain the Super Hornet for 30 more years. While not analyzed from a financial standpoint, this factor must be considered by DoN leadership since the F-35C is just beginning its life cycle.

In the course of this project, the authors identified several topics that warrant future discussion. These areas resulted from a lack of quality data to analyze.

First, it was identified the amount of flight testing required to certify the F/A-18E/F and F-35C were unknown. To provide reliable data in the future, the Navy needs to appoint NAVAIR engineers to develop detailed test plans for the certification process.

Second, security requirements were omitted from this CBA due to lack of guidance from the cognizant authority. Once this information is known, NFDS personnel can discuss security requirements with show sites to determine how it will be provided. This may prove to be a significant cost for the Navy.

Third, the value of recruiting leads was taken from a previous study conducted in 2012. It may prove worthwhile to discuss a different modeling method with the Navy Recruiting Command to determine an updated value for a potential recruiting lead. Furthermore, discussions with Navy Recruiting Command may yield a different valuation of the KI and Media Flight programs.

Lastly, the F-35C loses a great deal of potential benefit as compared to the F/A-18E/F through a lack of a KI and Media Flight program. Working with Blue Angels Public Affairs office and the Chief of Naval Information may generate a creative solution to the previously identified problem. The untapped potential benefit would greatly offset some of the F-35C's cost.

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